[*From "Transactions" Edin. Geological Society, Vol. IX.*]

TRANSACTIONS

OF THE

EDINBURGH GEOLOGICAL SOCIETY.

SESSION 1906-1907

Evidence of Contemporaneous Volcanic Action in the Banffshire Schists.

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(Read 19th Dec. 1906.)

THE only reference, so far as known to me, to the possible occurrence of contemporaneous volcanic rocks in the Banffshire schists is in the Geological Survey's memoir, "The Geology of Lower Strathspey." In a chapter on the petrography of the area, Dr Flett, after describing a section of a peculiar hornblende schist from about 300 yards above Ardwell Bridge on the Blackwater in the Cabrach district, which shows "little oval lenticles of calcite, which readily weather out, giving the rock a pumiceous appearance," follows up his description by the suggestion that "it may have been a vesicular basic sill, but the appearance of the rock suggests at once the possibility that it is a contemporaneous lava." I had probably read the paragraph indicated previously to my visit to the Cabrach in the summer of 1905, but if so, it had entirely passed from my mind, so that the raising of the question of the occurrence of contemporaneous volcanic rocks in the schists of that area must be considered an entirely independent suggestion. Moreover, the evidence which I have now to adduce leads me to conclude that the hornblendic schist in question is not the only—or in fact by any means the most typical—example of contemporaneous volcanic rocks there exposed. I hope further to be able to show that we have in this area not only exposures of interbedded vesicular lavas of more than one type, but that there are some of a more compact form; not only so, but that this manifestation of volcanic action in the Banffshire schists is characterised by the presence of coarse fragmental beds closely simulating, if they do not actually represent volcanic agglomerates, and possibly also (though this is no doubt more problematic) of finer fragmental

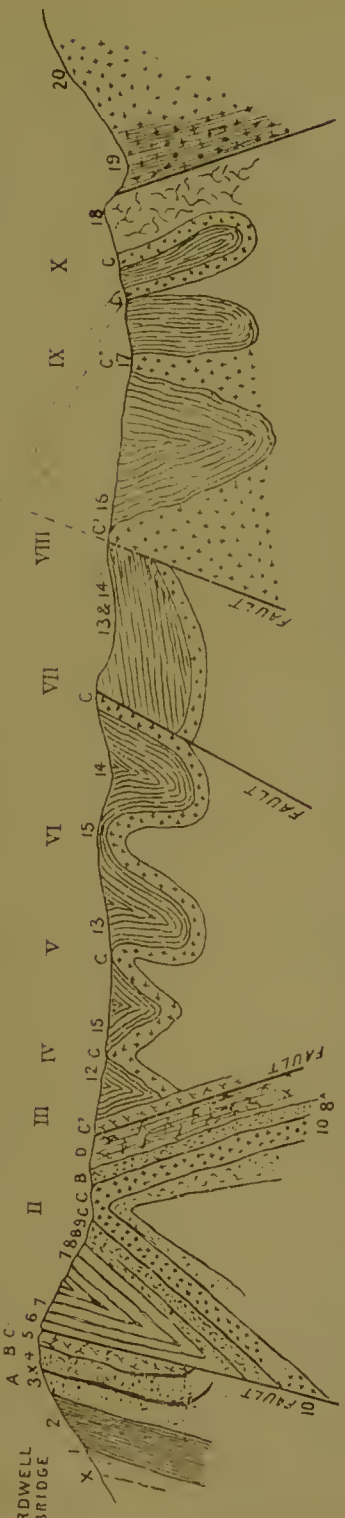
bands which were originally probably of the nature of fine volcanic ashes.

The first evidence of volcanic rocks in the Cabrach was discovered on the top of the hill (known as the Poorman) in the summer of 1905, about $\frac{3}{4}$ of a mile W.S.W. of the Richmond Hotel, at a point just beyond where the track from the hotel towards the top of Meikle Firbogs crosses a slight depression. There I found a number of blocks of a vesicular igneous rock, none of which were evidently in place, but which were so arranged with their long axes in a N.E. by N. and S.W. by S. direction, in such a way as to suggest that they had weathered out of a rock mass, at no great distance below the surface, having the general strike of its divisional planes in the direction indicated. On weathered surfaces the vesicles were empty or contained a little earthy oxide of iron, but on breaking up the blocks they were found to contain coarsely crystalline white calcite. At first I was disposed to consider that they might represent another outcrop of vesicular volcanic rocks belonging to the Old Red Sandstone period, and of which an example occurs on the opposite side of the river Deveron, about two miles distant, interbedded with sandstones of that period. But the matrix in the blocks in question was much more basic than in the case of the volcanic rocks associated with the Old Red Sandstone of the North of Scotland.

During the same visit coarsely fragmental blocks closely simulating an old volcanic agglomerate, the fragments consisting for most part of basic or what had originally been basic igneous rocks, were found in great numbers about $1\frac{1}{2}$ miles north-east of the place just indicated on the farm of Ardluie. The fragments proved on micro-section to be embedded in a greenish matrix composed of foliated and felted ferro-magnesian silicates, a fact which entirely precluded their being ranked as belonging to the Old Red Sandstone.

On subsequent visits in the autumn of 1905, and again in the summer of 1906, I found that what were presumed to be interbedded volcanic rocks were most typically developed in a river section on the Blackwater, extending from Ardwell Bridge for about 400 yards west of that point. This section I shall therefore now describe in detail. On the left bank of the river, within about 15 yards of the bridge, occurs the first vesicular band. It is a dark basic rock, somewhat decomposed and iron-stained, showing, on exposed surfaces, empty ovoid vesicles, some of which are over $\frac{1}{2}$ inch in longer diameter. The planes of foliation or schistosity are vertical, and the longer axes of the vesicles run with the strike, but make a considerable angle with the horizontal plane. This vesicular band is faced on its N.W.

side by rocks of the same character, but without vesicles. They might very well represent the massive part of the same lava flow of which the band just described might represent the vesicular selvage. The strike of these cuts the opposite side of the river at a point about 100 yards above the bridge, just where the high bank overhangs the deep pool — Poll à Bhocain — where there are no exposures of rock. On the right bank of the river, just as the high ground is reached, a series of dark schists is seen dipping S.E. at about 80°. These evidently fall on the eastern side of the vesicular band just described. Then comes, after a gap into which that band[1] if produced along the strike would naturally fall, a narrow band of grey quartzite about 3 feet broad. This is followed by a band 20 feet or more in breadth, of a dark rock which weathers with a peculiar pumiceous, irregular surface, but which shows on a fresh fracture numerous spots of white calcite. The rock is much crushed



SECTION ALONG BLACKWATER FROM ARDWELL BRIDGE WEST TO GABBRO BELOW BLACKWATER LODGE.

A, B, C, D, Various types of volcanic rocks. C?, Probably intrusives. X, Quartz-schist. 1 and 2, Black schist. 3, First vesicular band (vesicles empty) = A. × Narrow quartzite band. 4, Pumiceous vesicular band (vesicles $CaCO_3$) = B. 5, Green schist, highly foliated. 6, Quartz-schist. 7, Silvery mica schists, andalusite, etc. 8 and 8a, Pumiceous vesicular (vesicles $CaCO_3$) similar to 4 = B. 9, Black schist. 10, Massive hornblendic = C. 11, Vesicular (vesicles quartz) = D. 12, Mica schist similar to 7. 13, Quartz grits. 14, Mica schists often with andalusites. 15, Black schists with indications of fragmental character. 16 and 17, Possibly sills or bosses of crystalline igneous rocks. 18, Serpentine. 19, Foliated gabbro. 20, Crystalline gabbro.

[1] The presence at this point of much crushed vesicular volcanics showing lenticles of calcite has since been ascertained.

and would unhesitatingly be classed by the field geologist as an impure, crushed, crystalline limestone. This, if not the rock described by Dr Flett, is evidently of the same type, and its structure as revealed by the microscope would bear out the conclusion that it was originally a very pumiceous lava. Then follows a narrow band of an unctuous green schist which might very well represent—and which probably is from its microscopic structure and characters—a deformed basic igneous rock. Here occurs a decided fissure which probably represents the line of a fault. On the western side of the fissure, there comes a narrow band of quartz grit showing evidence of much crushing. Then follows a dark, highly fissile mica-schist, which is in turn succeeded by a beautiful, silvery mica-schist, showing andalusites and what appear to be small staurolites, but as no micro-section has been examined, the determination of the presence of the latter mineral is not final. A band of quartz grit follows, but its relations are not very evident. It is considered probable, however, that it may represent the band of quartz-grit just described, coming up on the other limb of a synclinal fold. From this point, for a distance of 50 yards or so, no outcrops are to be seen, and the first rock in place after this gap is similar to No. 4, that is the pumiceous, vesicular band, but much less crushed; but it so closely resembles that rock that there is every reason for concluding that it is that band repeated. Then follows a dark bluish schist, showing much crushing, after which comes a massive, dark green, much crushed hornblendic rock, of which micro-sections are submitted. The sequence at this point becomes somewhat difficult to follow, this green hornblendic rock and vesicular patches of the type of No. 4, but much less crushed, being mixed up together in inextricable confusion. In places the hornblendic rock weathers with a peculiar nodular surface; at others it shows streaky—sometimes patchy—variations in colour, suggesting a fragmental origin. But this may simply be due to crushing and foliation *in situ*. Another appearance, which consists in the occurrence of solid rounded nodules of compact rock 3 or 4 inches in diameter, surrounded by and embedded in vesicular rock, is much more difficult to explain, but suggests the conditions that might be expected to occur at or near the surface of a lava flow.

Specimen No. 12 is from one of these solid nodules which was taken from a band showing much lenticularly arranged calcite, while 10a and 10b are from a vesicular band in its immediate neighbourhood. These, as will be seen, are also of the type of band No. 4, though showing larger lenticles of calcite, and a darker, more compact base. Then follows a band of dark mica-schist with andalusites, and in a very obscure outcrop, not more than

3 feet across if as much, this is succeeded by a crumbling rock which breaks down into rough nodules in which it is difficult to obtain a fresh fracture. It is a dark, micaceous, schistose rock, showing numerous white lenticles, which are somewhat local in their distribution, but in the patches where they do occur are often seen in close set aggregates. A micro-section of this rock is submitted. It shows lenticles of granular quartz and a micaceous substance, the latter in sparing quantity, set in a matrix of fine biotites and felspars, and is exactly like one of the specimens of No. 4, except that the lenticles are of quartz instead of calcite. Whether a variety exists, as in the case of that rock, showing hornblende in addition, can only be settled by examining a number of micro-sections from this particular outcrop. Following this band on the west comes a band of dark quartzite similar to No. 3, and this is faced on its western side by a band of dark frilled schist, which is separated by a large fissure marking the line of a fault from a dark, finely crystalline hornblendic rock, closely resembling a dolerite. This forms the centre of fold iii., and as all the types of the volcanic rocks have now come under observation in the section just described, it will be unnecessary to follow the rock sequence farther along the course of the river.

As will be noted, four types of volcanic rocks have been seen. These briefly are :—

Type A, represented by No. 2 Compact Vesicular, cavities empty or filled with $CaCo_3$.

Type B, represented by Nos. 4, 8, and 8a, Pumiceous Vesicular with $CaCo_3$.

Type C, represented by Nos. 5 (?) and 10, "Nodular Igneous," Compact Hornblendic Beds.

Type D, represented by No. 11, Micaceous Vesicular, cavities with quartz-mica aggregates.

I shall now trace the development of these rocks in the surrounding area in so far as we have indications of their presence in the various limited exposures that exist.

Type A.—Indications of A occur in the direct line of strike on the top of the Poorman, the point at which vesicular volcanics associated with the Banffshire schists were first observed. On following the line of strike still farther to the S.E., blocks of an exactly similar rock were found in a small surface opening on the moor overlooking the hamlet of Ardivalloch, about $\frac{1}{4}$ of a mile N.E. of a small hill-croft locally known as Mount Pisgah. Again, in the line of strike to the N.E. of our central section, the presence of similar rocks is indicated by the presence of surface blocks of similar character on the hillside behind the U.F. Church at the Lower Cabrach : while a series of beds, which

are probably referrable to this particular manifestation, are seen on the moor by the side of the old road leading up from the farm of Drywells to the N.W. They dip to the S.E. at about 45°, are of a dark grey colour, much decomposed, and show cavities which are somewhat irregular as regards size, shape, and distribution, and contain a little earthy oxide of iron.

If we are right in classifying these manifestations as indications of the same band, it would thus extend for a distance of quite 4½ miles along the strike.

Some indication of the presence of vesicular rocks of this or a similar type occur in association with the coarsely fragmental rocks near the farm of Ardluie. These will be referred to when the latter are described in detail.

Vesicular rocks of this type do not appear to be repeated in any of the numerous folds that occur between Ardwell Bridge on the Blackwater and the mass of gabbro which occurs about 2 miles west of that point.

Type B.—The pumiceous vesicular rocks have not been seen, at least in their typical form, elsewhere than in the sections on the Blackwater within 400 yards of Ardwell Bridge. But a rock which is probably a modification of this rock is seen on the Charach at a point just a little to the N.W. of a line drawn along the line of strike of the band A in the Blackwater section to the U.F. Manse. Here the rock is more compact, showing occasional white spots which are, however, rather of the type seen in the manifestation D. The evidence that it does represent No. 4 (type B) is mainly stratigraphical, and lies in the fact that it is faced on its eastern side by a band of quartzite of much the same characters and thickness as occurs on the eastern side of No. 4 in the Blackwater section. With regard to the other bands of this type in that section, these are most easily explained as repetitions of band No. 4, due to isoclinal folding. A rock, associated with a dark-green, hornblendic nodular rock of type C is seen at a point just to the east of the gabbro mass on the Blackwater, exceedingly like the rock supposed to represent it in the Charach section.

Type C consists of dark-green, usually fine-grained, compact hornblendic rocks, often much crushed. They are illustrated by two micro-slides which show marked foliation, the minerals being drawn out in streaks with occasional lenticular eyes of unfoliated rock. They weather in parts with a peculiar nodular surface. Hence they have been named for shortness, "The Nodular Igneous." Apart from this feature, however, they occasionally exhibit a coarsely fragmental appearance on account of local differences in colour, which exhibit a patchy as well as a streaky distribution, and it is difficult to decide whether

this is due to their original condition or is a feature superinduced by subsequent crushing and foliation *in situ*. The occurrence of rounded nodules of compact rock embedded in a vesicular matrix strongly suggests, however, an original structure to whatever cause it may be eventually attributed. A modification of this type, due to intense crushing and foliation, is in all probability band No. 5. A similar rock is seen by the roadside between Ardwell Bridge and Crofthead, nearly opposite the point where the footpath strikes off to Invercharach. It there dips at about 60° to the N.W. Band No. 5 is microscopically of the same character as rocks of type C. Coming below the "Pumiceous Vesicular," it is in the same stratigraphical position as the compact, hornblendic schist in the adjoining anticlinal fold. A similar rock of schistose character has been seen in association with the coarse fragmentals, and dipping like them at about 45° to the S.E. on the opposite side of the valley from Ardluie farm.

Apart from the dark, hornblendic rocks associated with, and generally if not in every case forming the centres of the numerous folds on the Blackwater to the west of those described, a number of outcrops of similar rocks are found at a distance from that section. These are (1) in a field above the farm of Lesmurdie, about 1½ miles to the N.E., where a green hornblendic rock of a rather coarser felted texture is seen dipping to the S.E. at an angle of about 45°, and (2) a band of similar character is seen on a branch of the Aldunie Burn, which comes in from the N.W. Here it is underlaid by a soft, clayey, decomposing mass, which probably represents a decomposed serpentine. (3) At a point intermediate between this and the outcrop of rocks of type A, on the Poorman, a considerable block of rock of "nodular igneous" was found in a surface opening near the top of the Alt Spruit; (4) a typically nodular band is seen standing vertically in the Blackwater, near the centre of the bend where the river curves to the south, just below the gabbro, and (5) just to the N.W. of the preceding outcrop, where it is seen in contact with the serpentine, and apparently dipping below it at a high angle.

My reasons for considering these compact hornblendic schists as representing originally interbedded lavas, is that in folds i. and ii. they maintain a constant relation to the pumiceous vesicular type, while in the exposures at a distance from the Blackwater section they appear to maintain a constant relation to the rocks of type A. This may be somewhat doubtful in case (1) stated above, but is less doubtful in (2) and (3), while in (4) and (5) the rocks of type A are not represented. While the series of cores of the several folds on the Blackwater may be considered in this light—and though they are found to vary

from one another chiefly in regard to fineness or coarseness of crystalline character, this seems to be the most evident and natural view to take regarding them—they may also be considered from the point of view of their being sills. They always conform to the structural planes of the rocks among which they exist, and they have never been seen to cross them in any section. Exceptions in the case of folds iii., viii., and ix., are warrantable on the grounds of their highly crystalline character and the relative absence of foliation. As regards local metamorphism, on the theory that they are sills there really exists no evidence. The grade of metamorphism is very variable over the area, and it is often of a high grade at a distance from all visible igneous manifestations, as, for example, in the case of the andalusite mica-schists.

Type D.—Only one typical example of this rock occurs just at the second bend of the river, about 400 yards above Ardwell Bridge, though modifications of it occur as already stated on the Charach and at the bend of the Blackwater below the gabbro. A micro-section of this type is submitted. It differs from rocks of type B only in the substitution of quartz-mica aggregates for the calcite lenticles of that rock.

The fragmental series are represented by—

E. A coarse variety seen at Ardluie and Findouran.

F. A fine variety from a band of black schist about 30 yards, above the foot-bridge on the west side of fold iv.

Type E.—The coarse fragmentals have been met with in place on the Ardluie Burn, at a point just above the bridge on the road to Dufftown, where the bedding dips towards the S.E. at an angle of 45°. Evidence that they are fairly extensively developed is found in the numerous blocks of what looks like a volcanic agglomerate, which are scattered widely over the fields and fences on the farm of Ardluie on the west side of the valley. The pebbles of the agglomerate are for most part of a light grey colour, and often show porphyritic hornblendes and other ferromagnesian minerals; others appear to have been originally vesicular, while some show that character in perfection still. In a large block 2½ feet in diameter which lies in the stream opposite the farm of Ardluie, some of the included fragments are quite 9 inches in diameter, and are exclusively of igneous rocks. The specimen from near the bridge looks at one part as if the entire matrix was vesicular, giving the impression that the pebbles had fallen on and been incorporated in a lava flow before it had solidified. Another vesicular specimen—not found *in situ*, however—shows two pebbles of igneous character embedded in a vesicular matrix. Fragments of a non-local character sometimes appear in the agglomerate but are rare. One appeared

to be a light-coloured felsite. A micro-section of a pebble of coarse grit is also submitted, showing less secondary alteration than the grits in the immediate neighbourhood, from which, however, it was probably originally derived.

As regards the stratigraphical arrangements at this point, good reasons exist for considering that the natural sequence is here inverted. Green nodular schists lie below them and apparently above them, all dipping to the S.E. Further, the fragments in the agglomerate have been derived from rocks lying to the east and above them in vertical position, *e.g.*, the vesicular fragments and those showing porphyritic hornblendes. These may now be represented by the porphyritic hornblendic slate, but unfoliated blocks showing porphyritic hornblendes, some of them composite, with bands of hornblendic slate in intimate relation with fragmental bands occur in numbers to the N.E. towards the margin of the serpentine.

A large block of rock of type C—of which a specimen is submitted—lies at the side of the Blackwater some distance below the foot-bridge, showing numerous pebbles of quartzite and a larger one of a yellowish felsite (of which a micro-section is submitted). This fact would tend to support the view that these compact rocks of type C are really interbedded lavas, though of course that would not be conclusive in the absence of other evidence. Again, foreign fragments which are uniformly of a dark colour are seen embedded in what is evidently the margin of the gabbro mass at a point just above the White Bridge on the farther side of that boss at the edge of the river. These are evidently xenoliths which have been involved in the gabbro as it broke through the overlying rocks on its original intrusion.

Type F.—A band of black schist somewhere on the west side of fold iv. was seen to exhibit a finely fragmental structure on a weathered surface, but this was not very apparent on a fresh fracture. Micro-sections, however, quite bear out the indication that they are of fragmental origin. This is probably best seen on examining a not too thin slide with a pocket lens. That they were not originally of sedimentary origin is borne out by their basic character and the fact that in some cases the characteristic structure of volcanic rocks is still visible under the microscope in their constituent grains. Indications of a fragmental origin are also observed in greenish or bluish schistose rocks from a point farther up the river where the pathway ascends at a sharp bend to the north. These, however, remind one of the greenish schists associated with the coarse fragmentals at Ardluie.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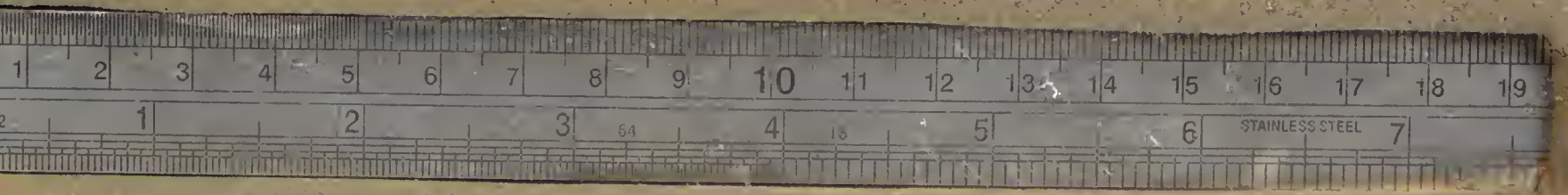
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